REMARKS

Reconsideration of the above-identified patent application, as amended, is respectfully requested. Claims 20-37 are pending in the application. Of these, only claim 20 is independent.

In the Office Action dated February 2, 2004, the Examiner objected to claims 26 and 27 due to certain informalities. By means of the present Amendment, these informalities have been corrected. Accordingly, withdrawal of the objections to claims 26 and 27 is respectfully requested.

In the Office Action dated February 2, 2004, the Examiner rejected claims 20-23, 28-34, and 36-37 under 35 U.S.C. 103(a) as being unpatentable over US 6,270,595 (Takayama et al., hereinafter US '595). The Examiner also objected to claims 24-25 and 35 as being dependent upon a rejected base claim, but indicated that these claims, as well as claims 26-27, would be allowable if rewritten in independent form and provided the objections to claims 26-27 are overcome. Applicants gratefully acknowledge the Examiner's indication that claims 23-27 and 35 contain allowable subject matter. However, for the reasons presented below, it is believed that all of the claims in the application, as amended herein, are in allowable condition.

Before discussing the prior art, a brief review of Applicants' invention is in order. According to the present invention for inductively hardening at least one surface (S, L) of a wall of a component, a liquid is filled into a gap (P) present between the surface to be hardened (S, L and the inductor (2) while said surface is heated. Besides cooling the side

of the wall (AS) opposite the side of the wall (IS) to be hardened by spraying liquid against it while heating takes place, at least one liquid jet (KI) is aimed at a zone (RZ) of the wall adjacent to the surface to be hardened (S, L), so that this zone (RZ) is precluded from heating by the inductor. Thus, Applicants' invention involves simultaneous heating and cooling of the workpiece.

The methods disclosed in US '595 are based on a thermal operation in which after substantially uniform, entire heating of a workpiece, such as a crawler belt bushing, cooling from either one of the inner or outer circumferential surfaces is first started and then cooling from the other circumferential surface is started. (US '595: Col. 5, lines 42 - 46; col. 6, lines 40 - 47; col. 7, line 66, to col. 8, line 4). Jet cooling such as water spraying or oil spraying are preferred to avoid uneven cooling (US '595: Col. 5, lines 63 - 65).

Cooling from the inside circumferential surface is carried out to reduce heat capacity in the core of the bushing which, in turn, expedites the later cooling from the outer surface so that this surface can be hardened deeper than the inner surface. (US '595: Col. 8, lines 29 - 43, lines 50 - 65; Col. 9, lines 38 - 44; Figs. 4, 5).

According to a first aspect, the teaching of US '595 aims at through-hardening workpieces made of medium or high carbon steels or medium or high carbon low alloy steels. After the workpiece is entirely heated to a quenching temperature, a quenching operation is carried out comprising the steps of

(i) advance cooling from either one of the inner and outer circumferential surfaces to reduce heat capacity at the core of the workpiece to provide a heat gradient, and

(ii) cooling from the other circumferential surface which is started after waiting for a certain time to reduce tensile stress and thus susceptibility to quenching cracks. Finally the workpiece is tempered either by self tempering or subsequent induction tempering from the inside. US '595: Col. 4, lines 38 - 65; col. 5, line 28 - 37).

By adequately arranging and relatively moving the induction heating coil 7 and the cooling nozzles 5 and 6 along the axis of the bushing 1, a time difference hardening method is realized. The inner surface cooling nozzle 5 and the outer surface cooling nozzle 6 are designed such that the nozzle 5 firstly cools an induction heated zone and a specified time later the nozzle 6 starts cooling. Also, nozzles 5 and 6 may be arranged oppositely with respect to the direction of movement. (US '595: Col. 6, line 19 - 39; Fig 3).

According to a second aspect of the teaching of US '595, a soft layer within the core of the workpiece is formed at a cross-sectional position closer to the inner circumferential surface while the hardened depth at the outside is larger than that at the inside. This U-shaped hardness distribution is achievable with materials that would lead to a through hardened workpiece if the inside and outside would be simultaneously cooled. Here, after heating a workpiece to quenching temperature, first the inner surface is cooled to either reduce heat capacity at the core of the workpiece or to make the core

partially unhardenable, and then after a while the outer surface is cooled (US '595: Col. 6, lines 64, to col. 7, line 25).

Other aspects of the teaching of US '595 are to first heat the workpiece, then cool the inner surface of the bushing while inductive heating from the outside surface takes place in order to restrict cooling of the outer surface, and finally quench the outside surface, not after having waited long enough to prevent the inside of the wall to be fully quenched. Carrying out this method with steels that would usually through-harden when being quenched simultaneously from the inner and outer circumferential surfaces or only from the inner surface makes it possible to obtain a soft layer within the core at a cross-sectional position closer to the inner circumferential surface. (US '595: Col. 8, line 29, to col. 9, line 37).

To perform the method known from US '595, two vertically aligned induction coils 8, 9 are used. Taking the relative movement of the induction coils and the bushing into account, a person of ordinary skill in the art would recognize that coil 9 will heat the outer circumferential surface while cooling from the inner surface takes place. The distance between the outer cooling nozzle 11 and the second coil 9 is adjusted to result in the time difference between the start of cooling the inner surface and the start of cooling the outer surface. (US '595: Col. 10, lines 9-30; Fig 5).

By means of scan induction heating and starting cooling the inside circumferential surface and the outside circumferential surface subsequently with time differences, bushings with either quench-hardened layers at the outer and inner circumferential

surfaces with a soft layer at the core, or with an outer circumferential surface being deeper hardened as the inner circumferential surface, may be manufactured by one cycle of operation. It is preferable to simultaneously cool from the inside and outside at least within a specified zone close to the upper end face and the lower end face of the bushing. By this method, a hardened layer at the end faces can be produced resulting in a bushing with a soft layer at the core completely enclosed by a hardened layer. (US '595: Col. 11, line 59, to col. 12, line 22; col. 21, line 46, to col. 22, line 67; Figs. 34, 35c).

Since the method according to US '595 does not carry out heat hardening from the inner circumferential surface and therefore does not use an induction heating coil for an inner circumferential surface, small-diameter tubular parts can be produced at low cost (US '595: Col. 4, lines 15 - 22). Although in Example 2 the induction heating coil is disposed on the side of the outer circumferential surface of the bushing, it may be disposed on the side of the inner circumferential surface of the bushing. However, it is preferable to carry out induction heating from the outer circumferential surface side taking the operating performance of the hardening system into account. (US '595: Col. 18, line 64, to col. 19, line 3; Col. 10, line 31 - 37).

From the above description, it is clear that all alternative aspects of the teachings disclosed in US '595 lack the fluid filled gap between the inductor and the surface to be hardened, as required in claim 20. Also, claim 20 requires simultaneous heating and cooling in contrast to the successive heating and cooling steps taught by US '595.

According to US '595, the workpiece is entirely and uniformly through heated beforehand, and only after at least one of the inside or outside surfaces has reached quenching temperature, controlled cooling of the surfaces is started in order to create a hardness profile which stretches across the whole cross-section of the bushing's wall. Due to that, and because of heating only from the outside, preliminary through heating has to be carried out in any case.

In contrast, claim 20 requires filling a liquid into the gap (P) and spraying a liquid jet (KA) "during heating." Thus, as many areas as possible are from the first precluded from heating in order to prevent these areas from losing toughness. That is true especially for the outside wall of the workpiece, which has to be prevented from being hardened through. As a result, only the surfaces of the guide paths are hardened.

The idea of simultaneously heating and cooling the workpiece is not disclosed or suggested by US '595. Accordingly, it is believed that claim 20 and its dependent claims are patentable over US '595.

The same applies with regard to the other prior art cited by the Examiner, namely, US 4,531,987 (Pfaffman et al., hereinafter US '987) and US 4,786,772 (Umemoto et al., hereinafter US '772).

The object of US '987 discloses a method for creating a hardness pattern P in the spaced inner surfaces 30a, 32a of the various lobe sections 20, 22, 24 of the workpiece bore B. To this end, there is provided an inductor C forming a component part of a combination inductor and quench head assembly D. For this purpose, inductor assembly

D is of an outer shape or configuration generally matching, but smaller than, the cross-sectional shape or contour of the workpiece bore B. (US '987: Col. 4, line 59, to col. 5, line 3; Fig. 8).

Assembly D is fixedly mounted and supported in place on the upper end of a mandrel 40 having an axial passageway 48 there through for the passage of quench fluid to the inductor and the quench assembly D. (US '987: Col. 5, line 3 - 12; Fig. 1, 4).

The liquid quench medium for a primary quench directed out the laterally open discharge ends 228 for impingement against and quenching of the heated bore wall surfaces 30a, 23a is supplied through passageways 226. Supply of primary quench liquid can be selectively energized. (US '987: Col. 10, lines 10 - 14, 30 - 35).

The workpiece A is supported in a position directly above the inductor and quench head assembly D with the open end of the workpiece A facing downwardly. Vertical relative movement of the aligned workpiece A and inductor assembly D toward one another causes entry and passage of the inductor assembly D into and upwardly through substantially the full axial extent of the workpiece bore B to a limiting inward position therein immediately contiguous the closed inner end 12 of the bore. (US '987: Col. 11, lines 21 - 33; Fig. 4).

By means of the primary quench arrangement the bore wall surface portions 30a, 31a of the workpiece bore B are progressively quenched and hardened as they become progressively heated to proper temperature and depth by the energized inductor C during

the passage of the inductor and quench head assembly upwardly relative to and within the bore B (US '987: Col. 10, lines 58 - 54).

Additionally, a secondary quench arrangement for producing a flood of quench liquid flowing across and overflowing completely around the top end of the assembly D is also provided. This quenching takes place when the assembly D is in its innermost position in the bore B and serves for impingement of cooling liquid against the innermost end regions of the bore wall surface portions 30a, 32a, after they have become heated to adequate depth by the inductor C. (US '987: Col. 10, lines 55 - 65). Secondary quenching can be selectively supplied. (US '987: Col. 11, lines 8 - 10).

If desired, quenching liquid may be directed against the external surfaces of the workpiece walls 30, 32, 34 through quench rings 294 for the purpose of maintaining these walls cooled during the processing of the workpiece A (US '987: Col. 12, lines 13 - 29).

The combination of the secondary quench from the top discharge opening 262 with the primary quench from the laterally outward directed lower discharge openings 228 assures the formation of an approximately uniform hardening pattern P throughout substantially the full axial extent of the bore wall surface portions 30a, 32a from the open end 14 of the bore B up to the closed end 12 thereof (US '987: Col. 14, lines 10 - 17).

Simultaneously with the initiation of the secondary quench the inductor C is de-energized after a momentary time delay after the inductor assembly D reaches and is stationed in its limiting innermost position within the workpiece bore B at the end of its passage inwardly thereinto. This is applied in order to obtain in the innermost regions an

adequate heated depth and a hardening pattern which is of uniform character with that of the rest of the surfaces. (US '987: Col. 14, lines 18 - 44).

The object of US '987 is particularly applicable for inductively heating and quench hardening the full axial extent of a three-lobed internal bore or passage in a thin walled steel workpiece commonly known as a tripod housing used in the drive assembly of a front wheel drive vehicle (US '987: Col. 1, lines 12 - 17).

With method known from US '987, inductor and workpiece are moved vertically relative to one another to cause the energized inductor to pass upwardly through the bore and progressively heat the bore wall surface. The heated surface is then progressively quenched to harden it by means of a quench head located directly below the inductor and passing upwardly through the bore along with the inductor. (US '987: Col. 1, lines 40 - 51).

Such methods are not suitable for use where the bore is open at only one end. The quench head below the inductor is restricted and prevented from passage through the bore completely to the inner end thereof. Moreover, the innermost end portions of the bore wall are not inductively heated to the necessary depth. (US '987: Col. 1, lines 65 - col. 2, line 27).

With the method according to US '987 it is possible to surface harden all or portions of the wall surface of a workpiece bore closed at one end the hardening extending substantially to the closed end of the bore having adequate depth throughout the full axial extent. (US '987: Col. 2, lines 30 - 35).

The invention as set forth in claim 20 is patentable over US '987 because this reference also lacks the feature of filling the gap with liquid during induction heating. In fact, US '987 suggests to flood and overflow the gap between inductor and the walls of the bore with cooling liquid by means of the secondary quench arrangement, but that explicitly happens after the inductor has been de-energized. Thus, the homogenizing effect of a water filled gap on the induction field is neither discussed nor suggested in US '987.

The present invention and US '987 deal with the same workpiece. But, while US '987 aims at axially reaching and hardening the wall surfaces up to the closed end of the bore, the present invention provides for a method to harden sections limited in axial direction.

The inventive sprayers located at the perimeter of the inductor cannot be compared with the primary quench arrangement disclosed in US '987. The inventive method is not a progressive method, but rather the inductor is completely inserted into the workpiece and stationed there before processing begins. With the inventive method, primary quenching in the sense of US '987 is achieved by filling the liquid into the gap. The liquid issued through the sprayers is only additionally applied to limit the hardened surface sections.

Turning next to US '772, this teaches a plurality of spaced apart ring bodies 2 disposed along the longitudinal direction of a pipe 1, each being parallel to one another and having one water tube 4 at the top thereof. As topmost ring only a water tube 4 is

provided. The rings 2 are independent of each other in terms of water passage, but are electrically connected to each other. The cooling water tubes 4 function as induction heating coils since they are connected to the heating coils 3. Into the passage 6 of the cooling water tube 4, cooling water W_2 is supplied so as to start the cooling of the object pipe 1 within not less than one second after completion of the heating. On the inside wall of the cooling water tube 4 there are provided a large number of nozzles 7 so as to inject the cooling water jets toward the object pipe 1 in a direction inclined to the longitudinal axis thereof. A cooling water film 30 is formed uniformly on the surface by the nozzles 7 preferably at an angle of 30 to 60 degrees. (US '772: Col. 2, lines 53 - 54; Col. 3, line 3 - 44; Figs. 1, 2, 3). Corresponding to the nozzles 7, it is possible to use nozzles 8 in connection with vanes 9 (US '772: Col. 4, lines 15 - 57; Fig. 4, 5).

Thus the use of the induction heating coil 15 readily allows slow heating of the outside of the object pipe 1 and subsequent formation of a uniform water film 30 on the outer surface of the object pipe 1 (US '772: Col. 5, lines 3 - 8).

The objective of US '772 is to provide an induction-heating coil that is capable of slowly heating a pipe from its outer surface, and then quickly and uniformly cooling the same surface, thereby improving its corrosion resistance. (US '772: Col. 1, lines 46 - 50).

The present invention is patentable over US '772 because according to its teachings, cooling is initiated only after the induction energy is switched off. There is no teaching or suggestion of filling a liquid into the gap and spraying a liquid jet during

heating of the surfaces (as required by claim 20) in US '772 or any of the other prior art of record.

Accordingly, it is believed that the present application is now in condition for allowance and a favorable action on the merits is respectfully requested.

Respectfully submitted,

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